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THE BFKL POMERON: CAN IT BE DETECTED?

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ABSTRACT

The BFKL pomeron is swamped by the soft pomeron, at least at $t = 0$.

Figure 1 shows data for the pp and $\bar{p}p$ total cross-sections. The curves[1] corrrespond to the exchange of the ρ, ω, f, a trajectories, whose contribution falls with increasing energy approximately as $1/\sqrt{s}$, and a rising soft-pomeron-exchange term which rises as $s^{0.08}$. There is a clear disagreement between the two Tevatron data points at $\sqrt{s} = 1800$ GeV. If one believes the higher CDF measurement[2], rather than the lower E710 one[3], then there is room for an additional contribution of at most 10 mb at that energy. This is the limit on how large any additional contribution can be at that energy.

One such contribution might be from a second pomeron. In particular, the BFKL pomeron[4] is thought to give a contribution that rises as fast as $s^{0.3}$ or more. The BFKL pomeron is purely perturbative, and so it is often said that it is not applicable to purely soft processes such as hadronic total cross-sections. However, a more correct statement is that in soft processes perturbative contributions are swamped by nonperturbative ones. Nevertheless they are present, and the data in figure 1 limit how large they can be. This in turn[5] limits how large they can be in the hard processes where they might be expected to dominate.

Analyses of the BFKL equation often incorrectly extend the integrations over the loop momenta to all values. If this is done, the separate terms in the BFKL equation are infrared divergent, but the divergences cancel between the terms. Nevertheless it is illegal to allow the integration to extend into the infrared region, because this is the nonperturbative region and the BFKL equation is purely perturbative. Likewise, it is not legal to allow arbitrarily large loop momenta, because this violates energy conservation.

The BFKL equation describes the emission of partons. To avoid the nonperturbative problems, we have to place some lower limit μ on their transverse momentum if

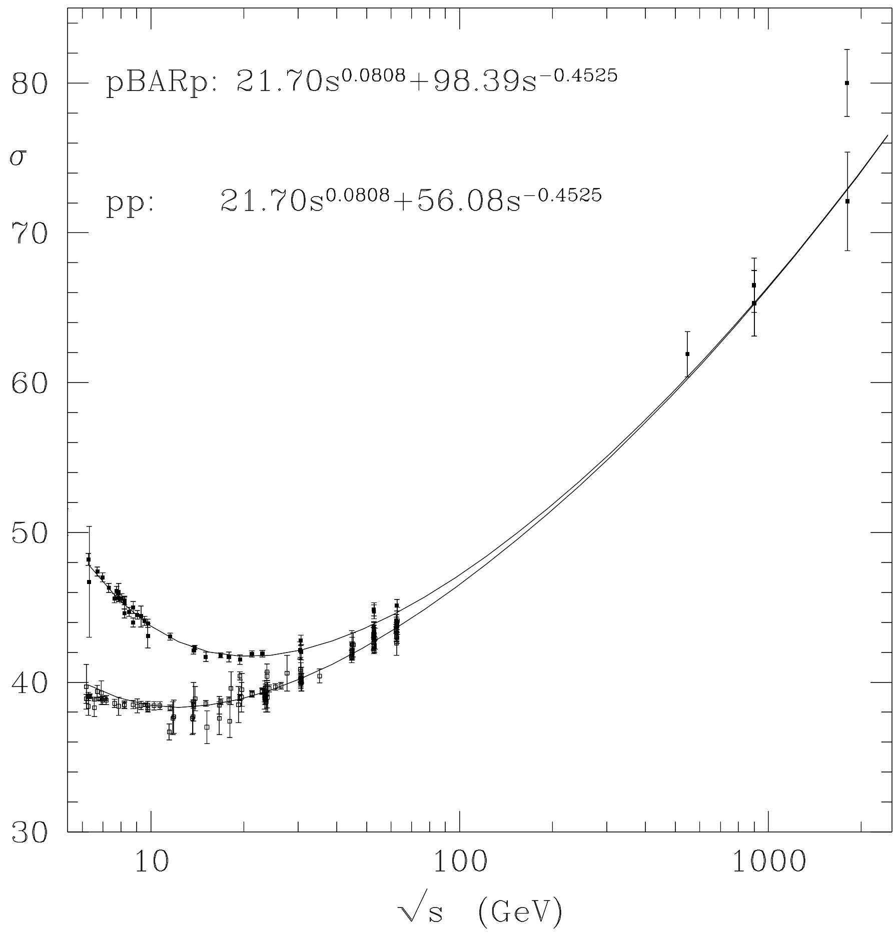

Figure 1: Data for pp and $\bar{p}p$ total cross-sections, with the fits indicated

we are to believe its predictions. In a general event, we may group the final-state partons according to their rapidities. As there is no transverse-momentum ordering, their transverse momentum is not correlated with their rapidity. So as we scan the rapidity range we find groups of partons all having transverse momentum greater than μ, with each such group separated by a group in which none of the partons has transverse momentum greater than μ. This we show in figure 2a, where the heavy lines have transverse momentum $K_T > \mu$, while the light lines have $K_T < \mu$. When we sum over all possible numbers of lines in a group with $K_T > \mu$ we obtain the hard pomeron H which we may calculate from the BFKL equation, while a group with $K_T < \mu$ sums to a soft exchange S. So the result is figure 2b. When we sum over all final states, we obtain for the cross-section

$$S + H + SH + HS + SHS + \dots \tag{1}$$

Obviously the sum must be independent of the value we have chosen for μ, provided

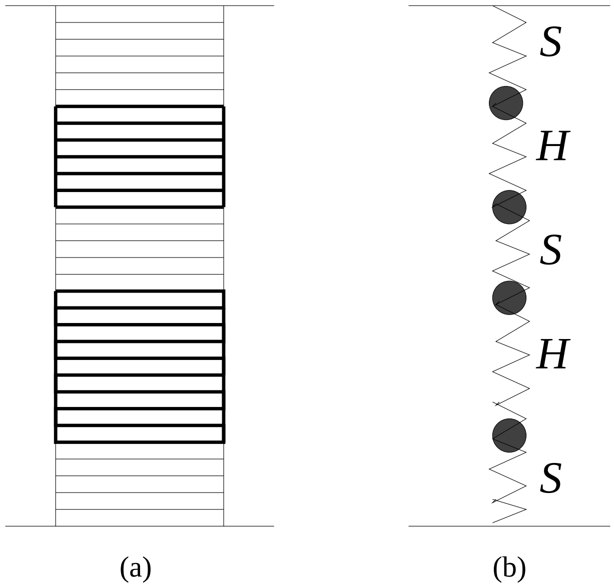

Figure 2: (a) alternating groups of partons with low and high K_T, with (b) their sum giving alternating soft and hard pomerons.

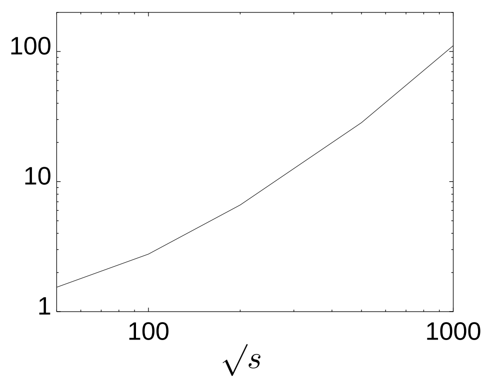

Figure 3: $\sigma_{qq}(K_T > \mu)$ in microbarns for $\mu = 2$ GeV

only that μ is large enough for the perturbative BFKL equation to be applicable to the calculation of H. It turns out[5] that μ must be at least 2 GeV in order that the hard contribution to the $\bar{p}p$ cross-section shall not exceed the 10 mb limit at Tevatron energy.

This is shown in figure 3, which is the calculated BFKL contribution H to the quark-antiquark total cross-section for the choice $\mu = 2$ GeV. It must be multiplied by 9 to get the contribution to the $\bar{p}p$ cross-section. Adding in the terms $SH + HS + SHS + \ldots$ mutliplies it by a factor which we have estimated to be at most an

Figure 4: Lowest-order graphs for $\gamma^* q \longrightarrow \rho q$

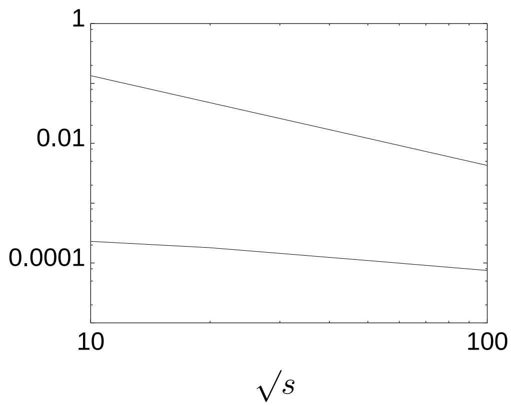

Figure 5: Pomeron-exchange contributions to the amplitude for $\gamma^* q \longrightarrow \rho q$; the upper curve corresponds to the soft pomeron and the lower to the BFKL pomeron

order of magnitude. At the quark level, the 1800 GeV Tevatron energy corresponds to 600 GeV, and the value of $\sigma_{qq}(K_T > \mu)$ at this energy shown in figure 3 is about as large as can be without conflicting with the data in figure 1. Notice that, if we had not required the total transverse energy of the emitted partons to be less than $\sqrt{s}$, the output for $\sigma_{qq}(K_T > \mu)$ would have been an order of magnitude larger.

Figure 4 shows the lowest-order contributions to the process $\gamma^* q \rightarrow \rho q$. As Q^2 increases, the two diagrams cancel each other more and more, a property known as colour transparency. The result of making extra perturbative insertions in the diagrams through the BFKL equation is shown in figure 5, again for the choice $\mu = 2$ GeV. This figure shows also the soft-pomeron-exchange contribution[6], which fits well to fixed-target data[7] and the H1 data from HERA (though ZEUS finds[8] a slightly larger cross-section). As may be seen, the BFKL contribution is some 2 orders of magnitude too small *in the amplitude* to explain the data.

Although the BFKL contribution is so very small, its properties are more or less as expected. For example, for $\sqrt{s} = 100$ GeV, reducing μ from 2 GeV to 1 GeV causes a huge increase in the amplitude for the soft process $qq \rightarrow qq$ — some two orders of magnitude. At the same energy and at $Q^2 = 1000$ GeV^2 the increase is only a

factor of 5. This property is called diffusion[9]: the effects of the hard interaction at the top of the BFKL ladder are felt all the way down it. For the amplitude $\gamma^*\gamma^* \to \rho\rho$, where there is a hard interaction at both ends of the ladder, the effect is even more marked[5]: the factor increase reduces to 3.

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